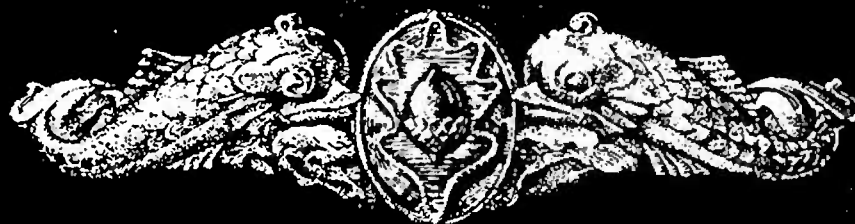


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THE INFLUENCE OF PRACTICE AND PITCH-DISTANCE BETWEEN TONES ON THE ABSOLUTE IDENTIFICATION OF PITCH

by

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THE INFLUENCE OF PRACTICE AND PITCH-DISTANCE
BETWEEN TONES ON THE ABSOLUTE
IDENTIFICATION OF PITCH

By E. B. HARTMAN, U.S.N. Submarine Base, New London, Connecticut

The term *absolute pitch* customarily implies an ability to name isolated musical tones—an ability possessed by few persons. The usual experimental test of this facility requires *O* to identify by name (C, G#, F, etc.) a series of tones presented singly, each being separated from the one preceding by a designated time-interval. If *O*'s average error of judgment satisfies a certain criterion (musical semitone or less), he is said to have absolute pitch; if his error exceeds the maximum allowed, he is not credited with absolute pitch.

Certain writers, Gough,¹ Köhler,² Meyer,³ and Mull,⁴ have attempted to show that *Os* who fail at first to meet the standard can, nevertheless, do so after training. The results of these studies, however, are largely equivocal, due to failure to control such factors as the number of tones in the series, the complexity of the stimuli, interstimulus time-interval, and pitch-distance between tones. It appears that what is needed is a careful determination of the effects of those factors upon absolute judgments of tones that are presented serially. How many tones can the average *O* adequately consider by the method of absolute judgment? How large must the pitch-

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¹Evelyn Gough, The effects of practice on judgments of absolute pitch, *Arch. Psychol.*, 7, 1922 (No. 47), 1-93.

²Wolfgang Köhler, Akustische untersuchungen III, *Zsch. f. Psychol.*, 72, 1915, 159-177.

³Max Meyer, Is the memory of absolute pitch capable of development by training? *Psychol. Rev.*, 6, 1899, 514-516.

⁴H. K. Mull, The acquisition of absolute pitch, this JOURNAL, 36, 1925, 469-493.

distance be between successive tones before *O* can make correct identifications? How are absolute judgments affected by increasing the number of tones or by decreasing the pitch-distance between tones? These questions, besides bearing on the issue of absolute pitch, are of general interest with regard to broader problems of discrimination. We should like to know, for example, how many different pitch-qualities the average *O* can identify absolutely for purposes of practical communication.

In the interest of extending our knowledge about the rôle of pitch in absolute judgments, this paper poses the following questions: How widely must a given number of pure tones be separated in pitch before the average *O* can make correct absolute judgments? What happens to the accuracy of absolute judgments of pitch when *O* is presented smaller and smaller pitch separations? How is the amount of information which *O* receives about the series related to the pitch-distance between tones? Are the effects of pitch-separation on absolute judgments significantly influenced by practice? How does disuse affect the ability?

APPARATUS AND PROCEDURE

Four series of nine pure tones, separated by either 50, 100, 200, or 300 mels, were recorded at a constant intensity. In recording each separate series, the tones were placed discretely on the surface of the record to permit individual presentation. Each tone was of 2-sec. duration and was preceded by a 6-sec. burst of white noise. A General Radio Company Interpolation Oscillator, Type 617-C, was used to generate the tones. In reproduction, an attenuator situated between the phonograph and Permoflux PDR-8 headphones allowed *E* to control the intensity. Since a soundproof room was not available, the experiment took place in a reasonably quiet room. *O* sat facing a chart bearing a column of circles numbered from 1 to 9.

Observers. Twelve *O*s with normal hearing were separated into four groups on the basis of their ability to make absolute identifications of 36 pure semitones between *C*₄ and *B*₄. Each group yielded an average semitone error deviating either side of 4.0 semitones by less than a quartertone.

Instructions. The following instructions were read to *O*:

This is a test to see how well you can identify tones. There will be nine tones, which you are to identify by number. Listen while I sound each tone and give you its number. Notice that tone number one is the lowest, and tone number nine the highest. Notice also that each tone is preceded by a burst of noise. (*E* sounded each tone once, beginning with the lowest, and called each by number.)

Now turn to your answer sheet and find Item 1. I am going to sound one of the tones. You are to decide which tone it is, then write its number opposite Item 1. You may find the chart helpful in making your decision. Notice that there are nine circles numbered one to nine, or low to high. They will help you picture the position of the tones.

Do not take a long time answering, for I wish to correct your judgment before giving you the next tone. Try not to think of the previous tone while waiting for the next. Since a burst of noise precedes each tone, you might regard the noise as a 'ready' signal.

O was then given the following sequence, which was repeated every 30 sec.: a burst of noise, given to 'wash-out' the perseverative effects of preceding stimuli (6-sec.), an interval of silence (1-sec.), a pure tone (2-sec.). The tones were presented in a predetermined order, designed in such a way that each tone followed every other tone an equal number of times. Loudness level was about 50 phons. *E* attenuated each tone to approximately equal-loudness with the help of an equal-loudness chart based on two normal *Os*. When *O* had identified a particular stimulus, *E* told which stimulus had actually been given.

There were two experimental sessions every week for eight test-weeks; each session consisting of 72 judgments, or 8 judgments per stimulus. During Session 10 (Week 5), *O* was not told which stimuli had been presented, in order that *E* might determine how much he was relying on correction. Similarly, Sessions 15 and 16 (Week 8) were uncorrected, to make possible an estimate of unaided level of performance. Two months after the completion of the main series, *O* was given two additional sessions to establish how much he had forgotten.

RESULTS AND DISCUSSION

Effects of pitch-separation. The customary treatment of the data from judgments of absolute pitch has been in terms of average error. The family of curves in Fig 1 expresses average error in mels against the week of practice, preserving the mel distance between tones as the parameter. These curves answer the question: By what pitch-distance, on the average, do the several experimental groups fail to identify the stimulus?

It will be noted (1) that no mel-group achieves 100% accuracy. This is perhaps understandable, inasmuch as perfect performance requires a total of 432 correct judgments per week—a rigorous criterion.

(2) In general, the smaller the pitch distance between tones, the smaller is the average error of judgment. The 50 and 100 mel-groups not only begin the experiment making smaller errors than do the larger mel groups, but they are able to maintain this advantage throughout the entire course of training.

(3) Learning curves for the 200 and 300 mel-groups drop sharply to asymptotes in about four weeks, while those for the 50 and 100 mel-groups show a more gradual descent, along with indications that learning is still occurring even at the end of training.

Gough, after training *Os* extensively to make absolute judgments of semitones on the piano, describes her learning curves as showing an irregular but gradual improvement, with no sign of a plateau at any point.⁵ Wedell's *Os*, on the contrary, judged tones separated by roughly $2\frac{1}{2}$ semitones and yielded curves which dropped quickly to asymptotes.⁶ The discrepancy between these two reports is accounted for

⁵ Gough, *op. cit.*, 86.

⁶ C. H. Wedell, The nature of the absolute judgment of pitch, *J. Exper. Psychol.*, 17, 1934, 494 f.

by the present findings, showing that with narrow pitch-separations improvement occurs slowly and is incomplete even after considerable training, while with wider pitch-separations improvement is rapid and complete within relatively few practice sessions.

(4) Abandoning correction causes the average error to increase for all groups. For all but the 200-mel-group, this increase varies directly with

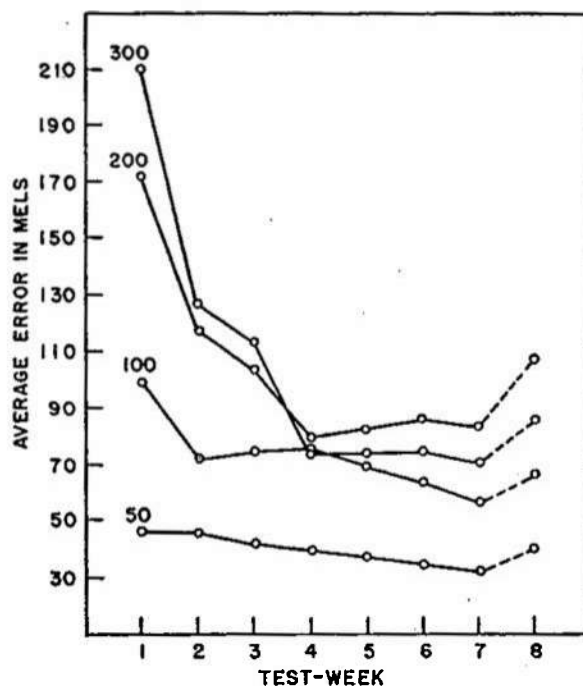


FIG. 1. ACCURACY OF ABSOLUTE JUDGMENTS OF NINE PURE TONES DURING EIGHT TEST-WEEKS

The values for Week 5 are interpolated, since one of the two sessions for that week was uncorrected and the results of the two sessions could not be averaged. The broken lines at right indicate the increase in error occurring when correction is withheld. Parameter is interstimulus pitch-distance in mels.

the size of the pitch-distance between tones. The anomaly is perhaps understandable in terms of the small number of Os employed.

(5) The wider the pitch-distance between tones, the more the average error is reduced by practice. Apparently, the degree of benefit derived from practice is not simply a function of the amount of time spent practicing, but varies also with the pitch-separation of tones in the series. This relation

is shown more clearly in Fig. 2, which plots the absolute reduction in average error occurring over seven weeks against the pitch-separation of tones in mels. The result is seen to be an approximate straightline function over the period of testing covered. This tendency for benefit from practice to increase with the pitch-separation, together with the fact that the average errors of the 200 and 300 mel-groups at the beginning of training are more nearly alike than are those of any two other mel-groups, explains how the 300 mel-group is able to surpass the performance of the 200 mel-group,

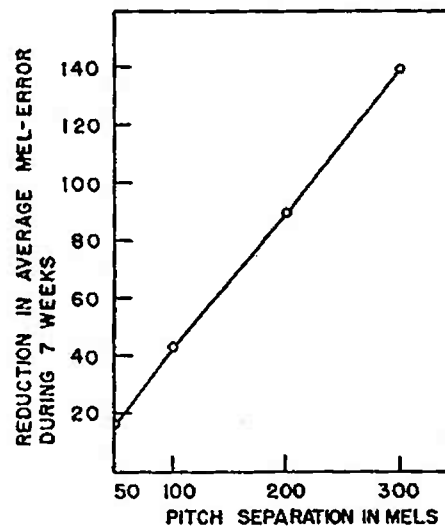


FIG. 2. EFFECTS OF SEVEN WEEKS' PRACTICE IN IDENTIFYING NINE PURE TONES AS A FUNCTION OF THE PITCH-DISTANCE BETWEEN NEIGHBORING TONES

even though the former's coarse separations entail errors of greater magnitude.

The fact that the average mel-error decreases with the pitch-separation cannot be taken to mean that *O*'s discrimination improves as the pitch-distance between tones becomes smaller and smaller. Consider the result of asking the *O*s to make absolute judgments of nine tones separated by infinitesimal frequency steps. Though the *O*s could perform no better than chance, their average errors, besides being of small absolute magnitude, would tend to be smaller than would those of a much coarser pitch-group committing occasional errors. Since all mel-groups in the present study were operating short of perfect identification, those groups judging the coarser pitch-separations were disproportionately penalized for guessing.

This fact becomes clearer when the percentage of correct judgments made by the various groups is taken into account, in which case it is found that the smaller the pitch-separation, the less often is the stimulus correctly identified. This is in agreement with Mull's finding that a reduction in the pitch-distance lowers both the number of correct identifications and the average error of judgment.⁷

Effects of pitch separation. Actually, the average error of *O*'s judgments, aside from being unduly influenced by the arbitrary choice of pitch-separation, is of less practical importance than is *O*'s ability to make consistent responses to particular stimuli. If, for example, we were to regard our tones as representing nine items of knowledge about a particular continuum, we might wish to know how the pitch-separation of tones affects the amount of knowledge which *O*s receive about the continuum. Garner and Hake have shown that a measure of amount of information transmitted is useful for this purpose.⁸

Fig. 3 plots the amount of information which each mel-group receives about its stimulus-series during eight test-weeks. The left hand ordinate represents the absolute transfer of information in bits per tone, while the right hand ordinate gives the efficiency of informational transfer in percentage (*i.e.* amount of information received over amount theoretically possible with nine stimulus-alternatives). These curves show several of the same characteristics noted in Fig. 1; namely, the clear differentiation of mel-groups, failure to reach the limit theoretically possible, differences in the shape of the learning function for the wider and narrower mel-groups, and the positive relation between mel-separation and benefit from practice. Of special interest is the fact that amount of transferred information varies directly with the size of the pitch-separation of tones in the series. Varying the separation by a factor of six (*i.e.* 300/50 mels) increases the efficiency of informational transfer from 40 to 70% at the end of training.

This is not in keeping with Pollack's finding that the transfer of information changes only a few percentages, even when the ratio between successive steps in the series is varied by a factor as great as 20 times.⁹ That this discrepancy in findings is due primarily to the extensive training given the *O*s in the present study is sug-

⁷ Mull, *op. cit.*, 479-482.

⁸ W. R. Garner and H. W. Hake, The amount of information in absolute judgments, *Psychol. Rev.*, 58, 1951, 446-459; Hake and Garner, The effect of presenting various numbers of discrete steps on scale reading accuracy, *J. Exper. Psychol.*, 42, 1951, 358-366.

⁹ Irwin Pollack, The information in elementary auditory displays, unpublished paper read before The Acoustical Society of America, May 8, 1952.

gested by the fact that the overall range of efficiency of informational transfer to our mel-groups on the initial week of training is 10%, a value which is in reasonably good agreement with the small percentage reported by Pollack.

The precise relation between interstimulus pitch-distance and information received at the end of training is shown in Fig. 4. Under the condition

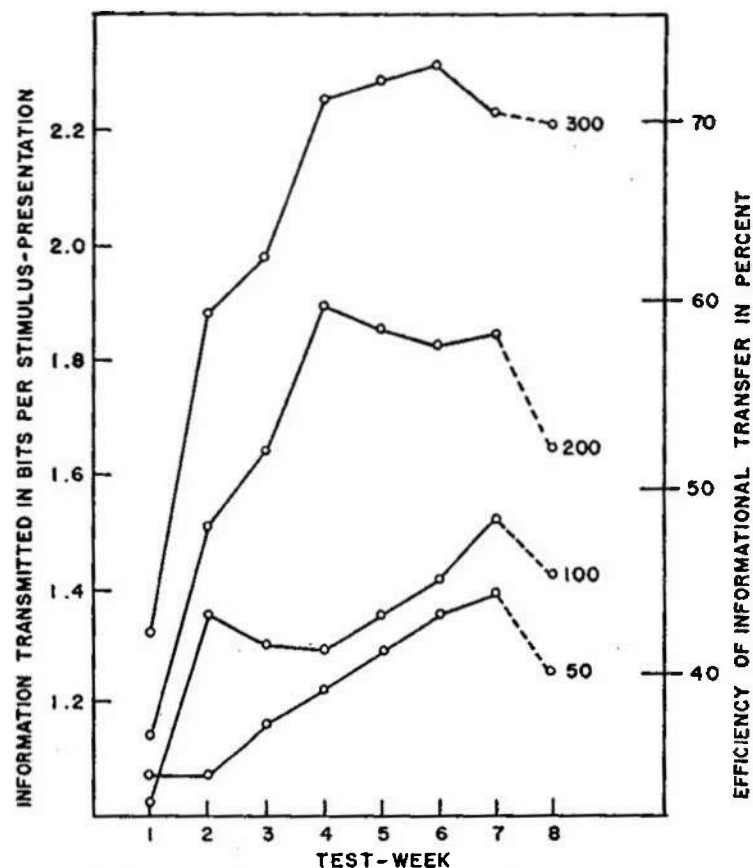


FIG. 3. AMOUNT OF INFORMATION IN ABSOLUTE JUDGMENTS OF NINE PURE TONES DURING EIGHT TEST-WEEKS

Values for Week 5 are interpolated for reasons explained in legend of Fig. 1.

in which O's judgments are corrected, the amount of information increases in an essentially linear fashion with the pitch-separation of tones. When correction is abandoned, however, the transfer of information is reduced in a way which suggests that the wider the pitch-separation, the smaller

is the informational loss. As we have already noted when considering average error, the 200 mel-group fails to conform with this tendency.

Although Fig. 4 gives every suggestion that a larger pitch-separation will result in still further informational transfer, several considerations advise against one's extrapolating this function. For one thing, above and below a frequency band extending from about 1000 to 6000 \sim , a given

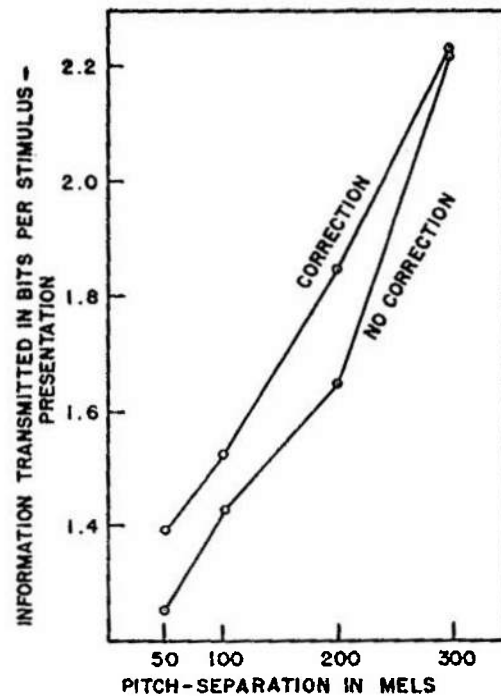


FIG. 4. AMOUNT OF INFORMATION IN ABSOLUTE PITCH-JUDGMENTS AS DETERMINED BY THE PITCH-DISTANCE BETWEEN NEIGHBORING TONES. The upper line represents the final week of corrected performance; the lower line, the final uncorrected performance.

mel-separation eats up the audible frequencies at an increasing rate. In addition to thus facing the unhappy prospect of running out of audio-frequencies, one encounters certain practical difficulties in controlling the stimulus for pitch at the frequency extremes.

Number of tones absolutely identifiable. Within specified frequency limits, the number of tones identifiable by the method of absolute judgment will depend, in large measure, on the criterion of accuracy one

chooses. By Wedell's criterion, which consisted of a single perfect identification of the stimulus-series,¹⁰ the *O*s (three in number) in our 300-mel group had learned their series in 1, 2, and 7 weeks, respectively, and two of them could still meet this criterion when uncorrected. Two of the 3 *O*s in the 200 mel-group learned their series, by the same criterion, in four weeks, one of them being able to maintain this level uncorrected. Wedell has stated that average *O*s cannot learn to identify 13 tones about 111 *DL*s of pitch apart.¹¹ Since the present study shows that *O*s can learn to iden-

TABLE I

THE RESPONSE PROFICIENCY EQUIVALENT TO AMOUNT OF TRANSFERRED INFORMATION
Values represent the number of perfectly identified stimuli necessary for an informational transfer equivalent to that received by each mel-group.

Mel-group	Number of tones perfectly identified	
	Week 1	Week 8
50	2-3	2-3
100	2-3	2-3
200	2-3	3-4
300	2-3	4-5

tify nine tones about 106 *DL*s apart and, under certain conditions, nine tones about 70 *DL*s apart, it appears that the difficulty experienced by Wedell's *O*s was caused not by the pitch-separation of stimuli, but by the absolute number of stimuli comprising the series.

Pollack employed an informational treatment of his data on absolute pitch,¹² hoping to circumvent the problem of choosing an arbitrary criterion of achievement, but discovered that he had chosen what was essentially a zero-error criterion.¹³ The treatment, nevertheless, provides a means for determining the number of tones, within fixed frequency-limits, to which *O*s are able to respond in an unequivocal manner. Table I summarizes for the first and final weeks of testing the response-proficiency equivalent to the amount of transferred information. These values answer the question: How many perfectly identified stimuli would it take to yield an informational transfer equivalent to that received by each mel-group?

It will be seen that on the first week of testing, no mel-group receives

¹⁰ Wedell, *op. cit.*, 500. Actually the present criterion is more rigorous than Wedell's, since stimuli were so arranged that a single perfect repetition always occurred in a context of more than nine correct judgments.

¹¹ *Ibid.*, 501.

¹² Pollack, *op. cit.*

¹³ While the information measure is insensitive to the magnitude of errors (Hake and Garner, *op. cit.*, 363), it is exceptionally sensitive to the number of errors.

more information from a 9-tone series than can be gotten from a 2- or 3-tone series, perfectly identified. This remains true for the 50 and 100 mel-groups throughout the entire experiment. Eight weeks of testing, on the other hand, enables the 200 and 300 mel-groups to boost their efficiency to between 3-4 and 4-5 tones, respectively.

As might be expected, the *O*s within any one mel-group differ in regard to the amount of information each receives. The response-proficiency equivalent to the information received by the best *O* in the 300 mel-group, for example, is perfect identification among 6-7 tones. Though slightly higher than the estimate based on the combined judgments of the three *O*s, this value still places the number of absolutely identifiable tones quite low. In this respect, the present results substantiate those of Pollack, who found that the information in combined absolute judgments rarely exceeded perfect identification among more than five tones, despite changes in the total number of tones, their pitch-separation, and, to some extent, *O*'s experience in judging.¹⁴

Forgetting. How much knowledge about the stimulus-series is lost in two months during which no absolute judgments were made?

Mull reports that the learning shown by her *O*s persisted for a month.¹⁵ Wedell's *O*s, after from 2-4 months' rest, relearned their series in less than one-third the time required initially, thus indicating a substantial savings effect.¹⁶ Gough noted some practice effects persisting over a period of a year and, furthermore, that the amount of ability retained was in some measure proportional to the degree of ability acquired through practice.¹⁷ Inasmuch as we have already noted that the informational benefit from practice is positively related to the size of the pitch separation between tones, Gough's findings suggest that the larger the pitch separation, the less information will be lost following a rest.

Fig. 5 plots the amount of information received by each mel-group on the final week of testing and the amount received two months later. It will be seen that all mel-groups show an informational loss after a two-months' rest. This loss, with the exception of that for the 50-mel group, is inversely proportional to the size of the pitch-separation. Two months' rest has a practically negligible effect on the transfer of information to the 300-mel group, while the same period of rest reduces the information received by the two narrowest mel-separations to a value only slightly greater than that obtained on the first week of testing. Thus, it appears that the stabil-

¹⁴ Pollack, *op. cit.*

¹⁵ Mull, *op. cit.*, 486.

¹⁶ Wedell, *op. cit.*, 498.

¹⁷ Gough, *op. cit.*, 86.

ity of judgment, during a two-month rest-interval as measured by resistance to a change in information received, shows a tendency to increase with the size of the pitch-distance between the tones in the series.

Effect of series. A question which arises in connection with the particular spacing of stimuli in the present study is whether pairs of tones which are equidistant in pitch are about equally confused in the absolute judgmental situation. An approach to this matter is provided by a partial overlapping, among three of the four mel-series, of the particular frequencies used as stimuli. These frequencies (1330, 1700, and 2104 ~) are sepa-

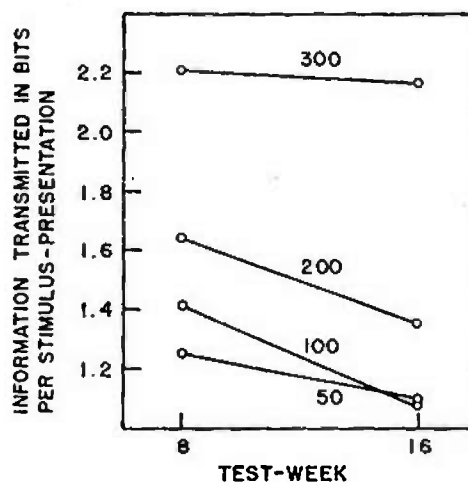


FIG. 5. EFFECTS OF A TWO MONTHS' REST ON ABSOLUTE PITCH-IDENTIFICATION
Parameter is interstimulus pitch-distance in mels.

rated by 200 mels, yet occupy different positions in the 50-, 100-, and 200-mel series. For the 50-mel group, the frequencies are tones 1, 5, and 9; for the 100-mel group, tones 3, 5, and 7; and for the 200-mel group, tones 4, 5, and 6. Should all these tones be about equally confused, we could conclude that confusion is due to a given pitch-separation, irrespective of the position of the tones in the series. Should the degree of confusion vary systematically, however, with the position of the tones in the series, we would be forced to conclude that pitch-separation is only one of the factors causing confusion in a serial situation—and not the most important one. Table II, which summarizes the extent to which the three frequencies are confused on the final uncorrected week of testing, makes it clear that stimuli separated by equal pitch-distances are confused accord-

ing to their position in the judgmental series. For example, tones 1, 5, and 9 are never confused by the 50-mel group, while the same frequencies (tones 4, 5, and 6) are confused almost one-third of the time by the 200-mel group.

Other writers have reported on these so-called *anchoring effects* which characterize absolute judgments of stimuli in a series. Wedell's graphs show that the average *DL*-error in judging pure tones is least at the extremes of the range.¹⁸ Wever and Zener maintain that *O*'s ability to make absolute judgments derives from a rapidly-formed

TABLE II
CONFUSION OF EQUAL PITCH-DISTANCES (200 MELS) BY THE 50-, 100-,
AND 200-MEL GROUPS

Mel-group	Stimuli	No. confusions	% confusion
50	1-5	0	0.0
	5-9	0	0.0
	1-9	0	0.0
100	3-5	7	7.0
	5-7	4	4.0
	3-7	1	1.0
200	4-5	20	21.0
	5-6	27	28.0
	4-6	3	3.0

body of knowledge about the character of the stimulus series; also, that an early acquaintance with the extreme stimuli facilitates the growth of such knowledge.¹⁹ Riker, upon observing that *Os* allegedly having absolute pitch performed no better at the extremes of the series than did *Os* allegedly without this ability, concluded that both groups of *Os* were about equally successful in using the ends of the range as frames of reference.²⁰ Pollack investigated the possibility that the increased accuracy noted at the extremes of his series might be due to a special identifiability factor inherent in the particular frequencies used.²¹ Partitioning the frequency range so as to exclude the centermost frequencies did not, however, appreciably increase the amount of information transmitted.

The anchoring effects noted in the present study, in view of the equal spacing of pitch-stimuli, have an important implication concerning the generality of the mel-scale for pitch. It is recognized (Garner,²² Stevens and Volkman²³) that sensory scales may be erected by a number of different procedures; also, barring the opera-

¹⁸ Wedell, *op. cit.*, 495.

¹⁹ E. G. Wever and K. E. Zener, The method of absolute judgment in psychophysics, *Psychol. Rev.*, 35, 1928, 466-493.

²⁰ B. L. Riker, The ability to judge pitch, *J. Exper. Psychol.*, 36, 1946, 331-346.

²¹ Pollack, *op. cit.*

²² W. R. Garner, Some statistical aspects of half-loudness judgments, *J. Acoust. Soc. Amer.*, 24, 1952, 153-157.

²³ S. S. Stevens and John Volkman, The relation of pitch to frequency: A revised scale, this JOURNAL, 53, 1940, 329-353.

tion of constant errors associated with the various procedures, that the resulting scales must be in reasonable agreement to be considered valid. Now, a given degree of confusion among tones judged by the method of absolute judgment appears to constitute a legitimate criterion upon which to erect a scale of equal pitches. If this is so, then the present results indicate that the mel-scale is not a valid scale of equal pitches for series judgment operations. Similarly, Garner has shown that a scale of equal discriminability erected on data obtained from absolute judgments of loudness does not agree with the loudness function based on other than series-judgment procedures.²⁴

Cross-sensory limits. Both Miller²⁵ and Pollack²⁶ have called attention to the apparent discrepancy between the estimated number of tonal *jnds* (about 340,000, according to Stevens and Davis²⁷) and the number seemingly manageable by the method of absolute judgment. Is this apparent inability to structure the pitch-dimension along absolute lines unique, or do we encounter similar difficulty with loudness and, indeed, with unidimensional experiences in other sense modalities? Pollack believes that *Os* have difficulty keeping track of more than 5 or 6 arbitrary designations along any one continuum, although he offers no evidence to support his view.²⁸ A few such studies may be found, however. Garner reports that the amount of information *Os* received about a series of 20 different loudness steps was roughly equivalent to perfect identification among only 3-4 stimuli.²⁹ Apparently, our limitations in structuring the dimension of loudness along absolute lines are of nearly the same order as are those for pitch, being smaller if anything.

A study dealing with absolute judgments in the sphere of spatial vision is reported by Hake and Garner.³⁰ The object was to determine the minimal number of different pointer positions which can be used in a standard interpolated interval to transmit the maximal amount of information about a given event continuum. The informational transfer in this case became asymptotic with ten pointer positions, a figure somewhat larger than the five which Pollack reports for pitch.

Finally, Guilford, in discussing the optimal number of steps to be used in rating scales, notes that various investigators have placed the critical number of steps between 5 and 9, depending on a number of considerations, including the training of the rater.³¹

These findings, while fragmentary, suggest that the normal organism's capacity to structure experience in the absolute manner is crudely developed, provided we limit our consideration to experiences occurring along a single sensory dimension. From the point-of-view of biological survival, however, this inability appears not too distressing. The bulk of stimuli which individuals must unequivocally identify in an absolute manner involves the simultaneous stimulation of several experiential

²⁴ W. R. Garner, An equal discriminability scale for loudness judgments, *J. Exper. Psychol.*, 43, 1952, 232-238.

²⁵ G. A. Miller, *Language and Communication*, 1951, 49-50.

²⁶ Pollack, *op. cit.*

²⁷ S. S. Stevens and Hallowell Davis, *Hearing*, 1938, 152-154.

²⁸ Pollack, *op. cit.*

²⁹ Garner, *op. cit.*, *J. Exper. Psychol.*, 43, 1952, 238.

³⁰ Hake and Garner, *op. cit.*, 358-366.

³¹ J. P. Guilford, *Psychometric Methods*, 1936, 267-268.

dimensions.²² Requiring *O*, then, to perform certain operations, viz., absolute judgments of pure tones, may be tantamount to requiring a type of performance he rarely, if ever, undertakes. Future research, in addition to carefully exploring the organism's capacity to make absolute discriminations in every experiential dimension, must undertake the problem of determining how judgmental accuracy improves with the degree of patterning in the stimulus.

SUMMARY AND CONCLUSIONS

Four groups, each containing 3 *O*s, identified by number each of 9 pure tones 48 times a week for 8 weeks. For any group, the 9 tones were separated by equal appearing pitch-intervals (either 50, 100, 200, or 300 mels). For the first seven weeks, the correct answer was given after every judgment. No correction was given on the final week. Forgetting was measured after two months.

With relatively small pitch-separations, learning takes place slowly and is incomplete even after eight weeks; with wider pitch separations, improvement is rapid and complete within comparatively few practice sessions. Within certain limits, all three of the following are positively related to the magnitude of the pitch-distance between tones comprising the judgmental series: (1) the number of subjective reference points which *O* can set up between two limiting frequencies; (2) the rapidity with which these points can be established; and (3) their stability. It appears, however, that the number of tones which *O* can handle adequately by the method of absolute judgment is quite small, perhaps 10, or less, by a reasonable criterion. Certain indications suggest similar limitations for other modalities.

²² Miller (*op. cit.*, 52), has stressed the rôle played by absolute identifications in the perception of the complex sounds we call speech.